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ABSTRACT

Nearly every culture has made important discoveries about the universe. Most cultures have searched for a better understanding of the cosmos and how the earth and human life relate. The discussion in this booklet considers time, space, and spirit. Time refers to a sense of history; space refers to geography; and spirit refers to life and thought. Several chapters on the history and concepts of astronomy, a time line related to these concepts, a map of the important geography related to these concepts, a glossary of important terms, and a list of several study suggetions are included. (CW)

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The Expanding Universe

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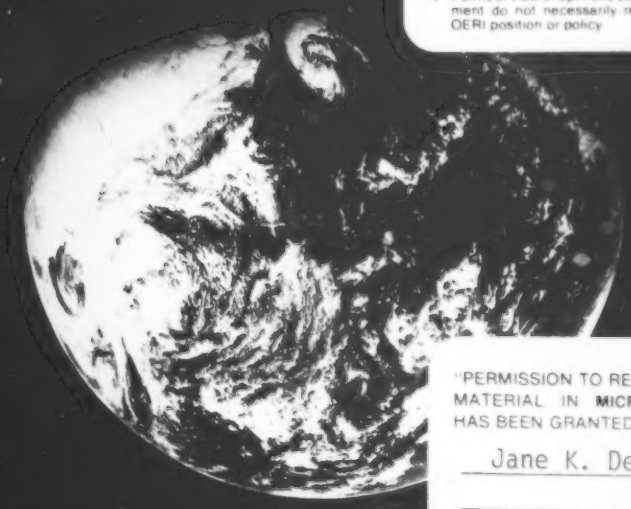

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A HAWKHILL LEARNING POWER BOOK

2

TIME, SPACE AND SPIRIT

KEYS TO SCIENTIFIC LITERACY

To the student,

This short book will help you understand our modern world. It has changed a lot since your parents were born. Even more since you were born. And it will change still more–much more–in your lifetime.

What is behind most of these big changes? Two things. Science and technology.

What can you do about it? The first step is to understand more about science and technology and how they connect with our world. Especially the ever-growing world of free democratic societies. One way to do this–the way this book follows–is to look at the world from three angles: *Time, Space* and *Spirit*.

Time means history. You can learn how science and technology have worked in the past and are working today.

Space means geography. You can learn where important things happened in the past and are happening today.

Spirit means life. The life of the mind. You can learn the key words, concepts and ideas that power science and technology (and society) today.

This book teaches about science, technology and society from all three of these angles–*Time, Space* and *Spirit*.

Read on.

This book belongs to:

The Expanding Universe

Bill Stonebarger
Illustrations by Lin Haley

Hawkhill Associates
Madison, Wisconsin

This book is one of a series of sixteen Learning Power Books in the *Time, Space and Spirit—Keys to Scientific Literacy* series. It is designed to accompany the video program of the same name.

The *Time, Space and Spirit—Keys to Scientific Literacy* series was written and produced with consultation from the History of Science Department at the University of Wisconsin-Madison.

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Part 1: How We Know About the Universe

Stonehenge

About four thousand years ago, at a place called Stonehenge in England, people placed some huge stones in a large circle. We think at least part of the plan was to keep track of the seasons. We do know that by sighting along mathematical arcs defined by the stones today, you can tell the precise calendar dates when spring, summer, fall and winter begin–called the spring and fall equinoxes, and the winter and summer solstices.

early astronomy

Early knowledge of astronomy was not special to England. In Babylonia, Egypt, China; in North and South America, India and Africa; just about every human culture has discovered important facts about our sun, earth and star cycles. Just about every human culture has searched for a better understanding of the cosmos, and of how earth and human life fit in.

two sides to astronomy

This better understanding has always had two sides. First, as at Stonehenge such knowledge can help people cope with practical problems caused by night and day, by the seasons, by the cycles of plant, animal and human life. It can also help travelers navigate in strange lands and on chartless seas.

for the wonder of it

The second reason for understanding the cosmos is just as powerful. For the sheer wonder of it. Who has not looked out at the starry sky and wondered. What are the stars? How far away are they? How did the stars and the sun and the planets get to be the way they are?

Huck Finn and Jim

These are some of the same questions that Huck Finn and his friend, Jim, asked and wondered about as they floated down the Mississippi River on their raft. Huck put it this way.

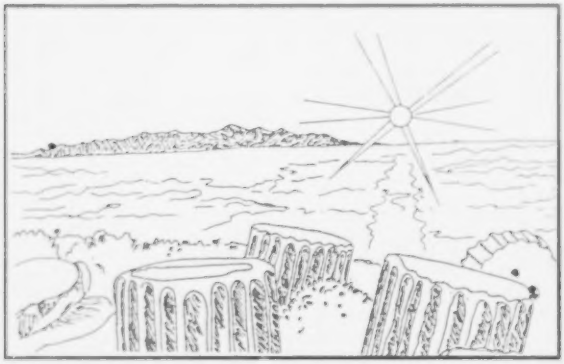
"We used to lay on our backs and look up at the stars, and wonder whether they was made or just happened. Jim, he allowed they was made. I allowed they just happened. I judged it would of took too long to make so many. Jim said the moon could a laid them.

"Well, that sounded kind of reasonable so I didn't say nothing against it, because I've seen a frog lay most as many, so of course it could be done. We used to watch the stars that fell too, and see them streak down. Jim allowed they got spoiled and was hove out of the nest."

the world's first scientists

Two thousand years before Huck and Jim, other humans sat on the hills overlooking Ionian Greece and asked some of these same questions.These men lived in the ancient city of Miletus, then a

Mediterranean port city. Often looked on as the world's first natural scientists, these men built new models of the universe in their minds. Some of these models were fantastic, others were startling in their imaginative accuracy.



new models of the universe

Thales, for instance, imagined the world was a giant disc that floated on a cosmic sea of water. Anaximander said the world was curved, not flat, and pictured it as a giant cylinder, surrounded by crystal spheres that held the sun and the stars. Pythagoras was the first to teach that the earth is spherical. All this around 500 B.C.

first atomic theory

A few years later in Athens, Greece, Democritus (the laughing philosopher) invented the world's first atomic theory. He also claimed that all the specks of light in the Milky Way were stars just like our sun. And that the moon was an earthlike body with mountains and deserts.

Aristotle's vision

Born about the same time that Democritus died, the most famous of all scientists of antiquity was Aristotle. His vision of the universe was as beautiful as it was influential for centuries to come. Aristotle pictured the earth as spherical in the center of a series of fifty-six concentric spheres. These spheres held the sun, the moon, the planets and the stars.

why things "fall down"

The heaviest part of the universe, said Aristotle, was the center–earth. That was why things always fell "down." Next heaviest was water. Then came air. Still lighter was fire, which was always rising up. And finally, highest and lightest of all, were the crystal spheres of the sky, which held the eternal stars. In fact, Aristotle thought these crystal spheres were a fifth element of no weight at all. An unchangeable aether.

first helio-centric universe

Aristarchus had the earth and the sun switch places, and built the first helio-centric (that is, sun-centered) universe. But how could this be, argued critics. If the earth were not the center of the universe, there would be no gravity. Instead of falling down, things would go flying every which way.

first one to measure size of earth

A few years later another Greek astronomer, Eratosthenes, actually measured how big the earth was! By carefully measuring the angle sunlight made in southern Egypt with the angle it made at Alexandria on the day of the summer solstice, and applying a little mathematics, he estimated the diameter of the earth itself with astonishing accuracy.

Ptolemaic System

In the second century A.D., Ptolemy, a Greek astronomer living in Egypt, simplified the picture first created by Aristotle and refined by later Greek astronomers. It was this picture, the famous Ptolemaic System, that all educated people in the Western World held to throughout the Roman Empire and the Middle Ages, a period of over one thousand five hundred years.

Copernicus starts a revolution

That Ptolemaic System was challenged in the early sixteenth century by a Polish astronomer named Nicholas Copernicus. Copernicus went back to the helio-centric system of Aristarchus, gave it a mathematical base, and started a revolution in science and society! A revolution that in its methodical way is still changing the world today. The revolution sparked by what we call modern science and technology.

wanted to make a better calendar

Copernicus, of course, was not conscious he was starting such a major revolution. He wanted to improve the calendar, to be more accurate than Ptolemy in predicting the positions of the planets, and more reasonable in explaining the strange "backward" motion of the planets that the Ptolemaic system had to imagine.

put the sun in the center

Why not, said Copernicus, simplify things by putting the sun at the center of those spheres, and have the earth and other planets revolve around the sun. With that assumption, indeed, the motion of all the planets did become more understandable. And Copernicus was a good enough mathematician to improve upon Ptolemy by making tables that could predict the positions of the planets, the equinoxes and the calendar adjustments with more accuracy than the old model.

Copernicus's famous book

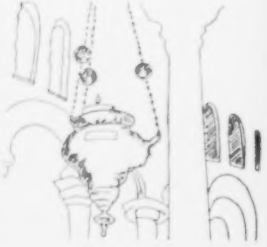
Copernicus's book On the Revolution of the Celestial Spheres was published in 1543, as Copernicus himself was dying. It became popular with scholars throughout Europe, though more often for its usefulness in calendar reform (and even in astrology) than for the literal picture it presented of sun, earth and planets. This idea, that the earth was not at the center of the universe, was very hard for people to accept then. (As it still is today!)

Kepler improves model

A German astronomer, Johannes Kepler, took the next step forward when he revised the Copernican picture by pointing to the need for elliptical rather than circular orbits for the planets. A brilliant mathematician, Kepler had available the most accurate observations yet made, those of the Danish astronomer Tycho Brahe. Using Brahe's figures he formulated the first laws of planetary motion.

Galileo watches an altar lamp

At the same time Kepler was working in Austria, a young university professor named Galileo Galilei was sitting in a church in Pisa, Italy, timing the back-and-forth movement of an altar lamp. He was timing it with the only instrument available for measuring short units of time, his own pulse. Which was good enough to discover the law of the pendulum.



the same motion as earth around sun!

Far more important, Galileo's simple experiments with the altar lamp were the first in a series of breakthroughs that brought together the motion of altar lamps, cannon shells, falling bodies and the motion of the earth around the sun!

conflicts with church

By that time, conflicts had heated up between the new scientific scholars like Galileo, and the Church authorities, determined to uphold traditional views. Galileo was cautioned many times to take greater care in how he presented his new views, lest he give offense to the Church and contradict Holy Scripture. Galileo was not a cautious man, however. Instead of taking greater care not to give offense, he boldly published a new book, Two New Sciences. In it he argued aggressively and persuasively for a Copernican universe. To make matters worse, the book was in the form of a dialogue and Galileo put the Pope's words into the mouth of a simpleton named Simplicio, a characterization the Pope did not appreciate.

Galileo is arrested, put on trial and convicted

Galileo was arrested and brought to trial in Rome. He was convicted in 1633 of disobeying the Church's orders. An old man now and almost blind, his only punishment was house arrest in his villa near Florence–on condition he take back his view that the earth was not the center of the universe. He did so.

Church wins battle, loses war

Though the Church won this battle, it lost the war. The evidence for the Copernican universe was too strong to keep down. And when Isaac Newton came along in the seventeenth century, the scientific revolution was well on its way to change the world more rapidly than it had ever changed before.

Isaac Newton

Isaac Newton escaped the plague of London in 1665 by retiring to his parent's farm in Woolsthorpe. He was not a very good gentleman farmer. He was a difficult man to get along with. But some think he was the greatest scientist who ever lived. Looking out his bedroom window, Newton himself tells us he saw an apple fall, and it gave him an idea. Could the force that makes the apple fall to the earth be the same force that makes the earth fall around the sun?

laws of motion and gravity

The answer he gave was, yes. And he proceeded to invent a whole new kind of mathematics, calculus, to prove his new laws of motion and of universal gravitation. Laws that were the foundation stones for much of science for almost three centuries to come. And laws which still today do service in astronomy, physics, chemistry and technology.

how the solar system "works"

Newton's discoveries not only confirmed the truth of the Copernican sun-centered system, but they made it much more precise, elegant and simple. Now there could be no doubt. The earth and the planets all move at high speeds around the sun. They keep moving by inertia. They are bent into their elliptical paths by a universal force of gravitation, continually "falling" around the sun. All this in just the same way that three centuries later humanmade satellites obey the same universal laws first discovered by Isaac Newton.

what about the other stars?

But what about the other stars? The stars besides our sun? Were they realy "fixed" in the distant sky, as earlier astronomers had supposed? And was our sun really the center of the universe?

a brother and sister team

About the time of the American Revolution, a hundred years after Newton's stay at Woolsthorpe, a German-English brother and sister team found answers to these new questions. Sir William Herschel and his sister, Caroline Herschel, lived in the English resort town of Bath. William played the organ at the Octagon, a church for the aristocracy. To keep body and soul together, he was also a music teacher, tutoring up to thirty-five pupils a week. With his sister Caroline, however, his real passion was for telescopes and for astronomy.

finest telescopes ever made

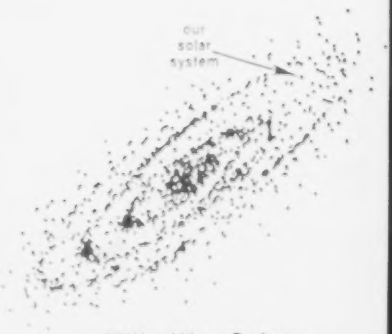
Together William and Caroline spent hour upon hour, week upon week, grinding the best telescope lenses ever made. They assembled these lenses into the finest telescopes ever made and used these telescopes to gaze into the night sky and learn.

a new planet and a new map of the universe

Over the next fifty years they found thousands of new stars in the sky. They found a new planet, Uranus. And most important of all, they drew a new map of the universe.

the Milky Way galaxy

Copernicus, Galileo and Newton had dethroned the earth from center spot. The Herschels dethroned the sun. They found that our sun was only one medium-sized star in a whole galaxy



Milky Way Galaxy

of stars, a galaxy they called the Milky Way. Our whole proud solar system, they said, was itself only one insignificantly small part of a much much larger star system, a galaxy. Our view of the universe was, indeed, expanding. And this was only the beginning.

other galaxies?

After the Herschels, throughout the nineteenth century, telescopes did improve, of course. As the catalog of known stars grew larger and larger.The Herschels speculated there might be other galaxies besides our Milky Way, but their instruments were not good enough to see that far. Such instruments would not be built for another 150 years.

a young man in Switzerland

The big picture, however, was not radically altered until a young man named Albert Einstein began his work in Berne, Switzerland around the beginning of the twentieth century. Just when people had adjusted to the Newtonian world, Einstein replaced it with a new world of relativity.

time and spaced

Until now, time and space had been taken for granted. Einstein took away this taken-for-granted time and space. Until Einstein there was here and now, there and then. Events unrolled neatly as though in a motion picture, or a scheduled trip. But that is all an assumption, pointed out Einstein, and nature does not need to follow our rules and assumptions.

a theory of relativity

If we assume, instead, that time and space themselves are relative, and not necessarily the same to some other observer at some

other spot in the universe, then all our scientific laws take on quite a different shape. The shape Einstein suggested was his special theory of relativity, later to be expanded into the general theory of relativity.

a way to test?

It is one thing to propose a new theory, another to prove it right. Who was right, Newton or Einstein?

It turned out there was a way to test. Eventually many ways to test. And in every case, it was Einstein's universe that passed the tests.

Edwin Hubble at Mt. Palomar

Since Einstein, our view of the universe has expanded still more. Edwin Hubble, a former lawyer, worked at the large new telescope at Mount Palomar in California. He discovered that our Milky Way galaxy was not the whole universe. In fact, it was itself only an infinitesimal part of a truly gigantic universe. A universe that was itself expanding continuously at enormous speeds. Even Einstein was astounded!

But if that were so, and the evidence was strong, what was the universe expanding from? Had it once been closer together? How close?

the Abbe Lemaitre sees a "big bang"

A Catholic priest at the University of Louvain in Belgium, the Abbe Lemaitre, proposed an answer to this puzzle. The universe had once been all one tiny "cosmic egg." There had been an explosion, a

"big bang," and in an instant, matter and energy moved outward faster and faster. And stars and planets were born. And galaxies and clusters of galaxies. And all moved faster and away from each other. And still farther away, and that is just what is still happening today in our expanding universe.

where is the evidence?

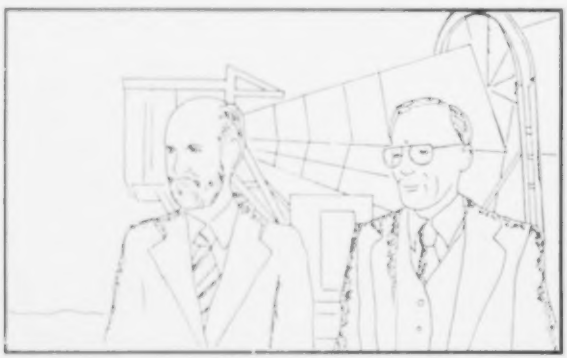
Was this just another wild idea? Where was the evidence? Some of the evidence came from Hubble himself. He found that the distant galaxies were indeed all moving away from our own galaxy at very high speeds. In fact, the ones farthest away (and there are not just a few, but billions on billions of these far away galaxies!) were also moving the fastest. Just what you would expect if there had been a big bang.

fits with the age of rocks

On careful checking with geologists, the time scale seemed to make sense. It all happened, the Big Bang that is, about fifteen billion years ago. That would fit with the age of rocks on earth, and on the moon.

Penzias and Wilson aim a radio antenna

Then very recently, from a surprising new source, came independent evidence of such a beginning. In 1964 two scientists at Bell Telephone laboratories, Arno Penzias and Robert Wilson, aimed a horn-shaped radio antenna at the sky and detect-



ed a faint radio noise that was not coming from any individual star or galaxy or black hole. It seemed to be coming equally from all directions.

listening in on the birth of the universe

After taking great precautions to eliminate all possible sources of error, including pigeon droppings in the antennae, they came to the conclusion that this radio noise was left over from the Big Bang explosion of fifteen billion years ago. They were listening in on the birth of the universe!

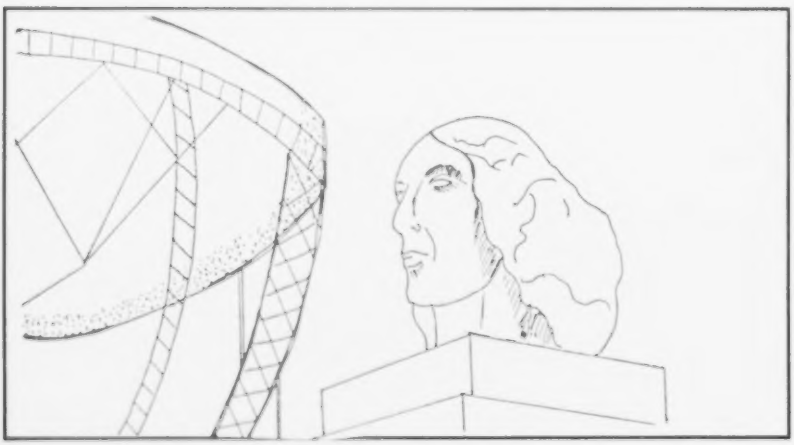
Their eavesdroping won them a Nobel Prize in 1978.

where do we go from here?

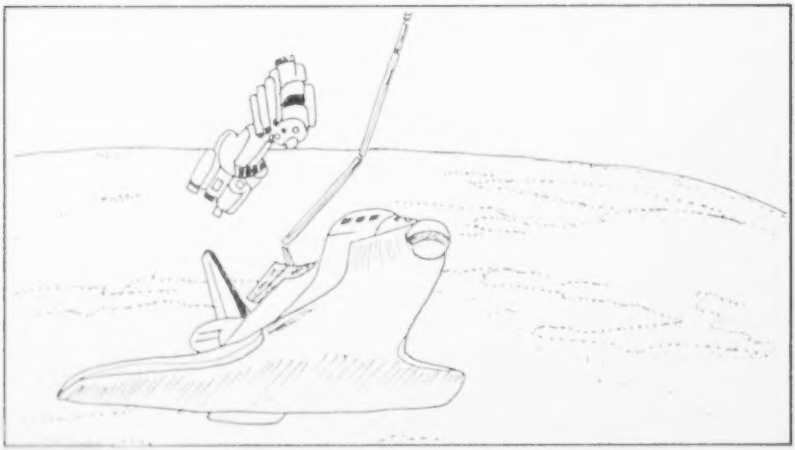
So today we stand on the threshold of what new suprises as we venture into outer space ourselves? As we put new telescopes on our space vehicles to hear and see new mysteries. Quasars, pulsars, black holes, who knows what next?

wonder out there and wonder in here

And yet, with all that space out there we need to remind ourselves once in a while that there is an equally large space in here. In the brains and minds of each and every one of us. As a poet said long ago, "It is not the immensity of space that should command our wonder, but rather the man who measured it."



Part 2: What We Know About the Universe.



days of exploration

When puppies are born, their eyes are sealed shut. The limit of their world is their mother's warm body. Before many weeks pass, however, not only do their eyes open, but their neighborhood expands, their muscles and senses begin to work together and days of exciting exploration begin.

Humans are similar.

Moving away from our own warm mother earth, already we have come upon as many surprises as puppies in a backyard. And we have only just begun our exploration of the universe. Let's look around and see just what we have found out so far.

how big is the universe?

First, how big is our universe?

Put it this way. If you tried to go from one end of the universe to the other in the fastest of present day spaceships, it would take you so long num-

bers would lose meaning. Trillions on trillions of years. If you managed to build a spaceship that could go at the fastest possible speed in the universe, the speed of light, it would still take not years, or hundreds of years, or thousands, or millions--but billions of years to make the trip.

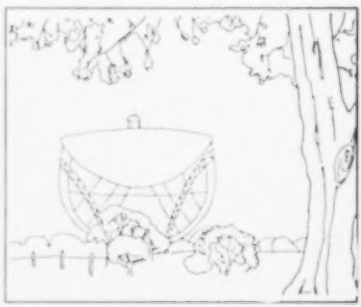
And even then, there might be billions of more years to go once we got into parts of the universe we have never seen or suspected before.

how old is the universe?

How old? Here the answer can be more definite, or at least we think so today. About fifteen billion years old, give or take a few billion.

how we know

Both of these estimates of distance and time come from careful study of stars and galaxies we can see through light telescopes,and more recently from new giant radio telescopes like the one at Joddrell Bank near Manchester, England. By analyzing the light and the radio signals we receive from these far away stars, we can make pretty good estimates of their size, their distance from us and the speed with which they are moving.



the "big bang"

What we find is a surprise. All of the far-off stars and galaxies are moving away from us at very high speeds. And the ones farthest away are moving the fastest. The logical assumption is that a long time ago they were all much closer together, perhaps very close together, and ever since a cosmic explosion they have been moving away from each other.

fifteen billion years ago

Counting backwards now, knowing present day distances and speeds, we find that this Big Bang must have happened about fifteen billion years ago.

A Belgian priest and astronomer, the Abbe Lemaitre, first put forth this theory of the origin of the universe with a Big Bang. One of his students, George Gamow, described it this way.

a "display of fireworks"

"The evolution of the world can be compared to a display of fireworks that has just ended. Some few red wisps, ashes and smoke. Standing on a cooled cinder, we see the slow fading of the suns and try to recall the vanished brilliance of the origin of worlds."

A long way from puppies.

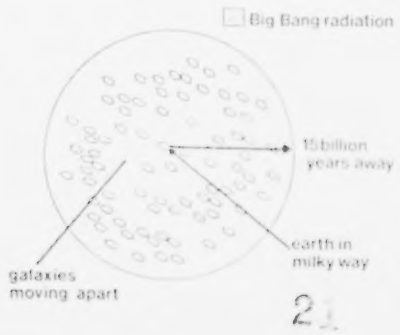
what is "inside" the universe?

What do we know of what's inside this expanding universe?

First of all, we have to watch that word "inside." Since Einstein we have a good idea that the universe is finite, but unbounded. We live, in other words, not in three, but in four dimensions. And the fourth dimension is time. And this fourth dimension of time makes all of space "curved."

"curved" space

To get some idea of what this might be like, imagine a balloon that is expanding. If you lived on the surface of the balloon (in just two dimensions) you would see all around you expanding, but there would be no boundaries. And yet the total space would be limited, finite. So, too, in our three dimensional world, when



you add the fourth dimension, the geometry becomes curved, unbounded, yet finite.

Having said all that, we still yearn to get a mental picture of what it's like out there, curved space or not. Let's try. If we switch from the largest possible view out there to a more comfortable view in here, maybe it will take a more sensible shape.

Earth in space

Earth, we are sure by now, is a spherical planet that is rotating on its own axis once every twenty-four hours, and moving in a large elliptical orbit around the sun once every 365 1/4 days.

one of nine planets

It is one of nine planets that are doing the same thing at differing distances from the sun and differing speeds of rotation on their own axes.

By now we have actually visited most of these planets in person. (Well, by proxy at least, with our humanmade spaceships.)

Mercury

The one nearest to the sun is Mercury. Our spaceship Mariner 10 visited Mercury a few years ago and reported that its surface was similar to the moon with many meteor craters and a heavy iron core.

Venus

Next out comes Venus. It is about the same size as earth, but not nearly as comfortable. It's surface temperature is over nine hundred degrees Fahrenheit. We know there are volcanoes on that surface, but they are deep beneath gloomy storm-driven clouds of carbon dioxide and sulfuric acid. Venus may be a planet where the "greenhouse effect" (carbon dioxide in the atmosphere reflecting heat back to the ground and warming the planet) has made a catastrophic difference. Venus may have had life in the past, but today it is certainly not a very promising spot for life.

Earth

Then comes Earth, blue white and alive. Earth is medium size as planets go, bigger than Mercury and Mars, but much smaller than Jupiter or Saturn. All the planets, of course, are much much smaller than stars like our sun.

planet compared to star

In fact, to get a picture of how much smaller, imagine that you were trying to fill a big star like Epsilon Aurigae with Earths. You would need about 35 thousand billion Earths to do the job!

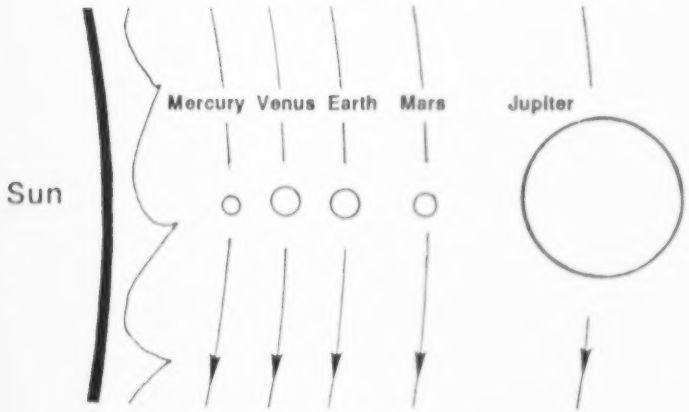
our moon

Close to Earth, and moving around it in a monthly orbit is the moon. Our moon. The only other body in the universe that has been walked upon by human beings.

Mars

Next planet out from the sun is Mars. For many years Mars was thought to be the only one of the planets besides Earth that might have life. Numerous probes of the Martian surface have so far failed to provide any evidence of life.

What we have found are unweathered craters where meteors have hit in past ages, extinct volcanoes fifteen miles high and dry river beds! These do suggest that in ages past Mars may have had water, or some kind of liquid on its surface.



Jupiter

Next out is Jupiter, the largest of the planets (larger than all the other planets put together). Jupiter is probably not solid anywhere. Most astronomers now believe it is made of mostly hydrogen, liquid inside, gas on the surface.

Jupiter's red spot

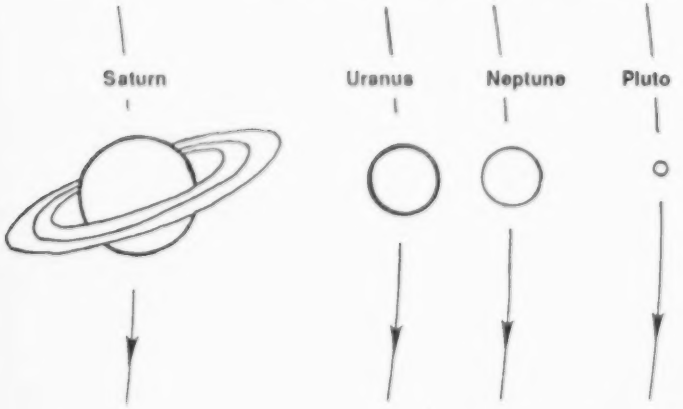
On the surface of Jupiter is a very large red spot, thirty thousand miles long by six thousand miles wide. A surface area larger than our earth! This red spot we know is a great whirling storm, though why it should persist so long we don't know.

the moons of Jupiter

Jupiter was the first of the planets besides Earth that was known to have moons. Galileo found the first four moons around Jupiter back in 1610. Today we know that Jupiter has at least fourteen moons.

Saturn

Saturn comes next, certainly one of the most beautiful sights you can see in a telescope with its impressive rings. Voyager II traveled through these rings taking spectacular photos and gathering new data on the chemical compostion of the rings, and of the thick atmosphere on one of Saturn's moons, Titan. It turns out that this atmosphere is made of nitrogen, ammonia and many simple or-



ganic compounds–the very same chemicals that life is made of on Earth!

clues as to how life began

We are just at the dawn of planetary exploration now. Future probes will no doubt give us more insight into not only how the solar system was formed, but also how life began.

Uranus

Uranus is next, though it is almost twice as far out as Saturn. Still farther out is Neptune, and finally Pluto.

asteroids for future space colonies?

Besides these nine planets, the solar system has an assortment of many other heavenly bodies, all orbiting our sun. Among the most important are asteroids. Asteroids are miniplanets really–that is, large chunks of rock ranging in size from a mile to a hundred miles in diameter. There are somewhere between thirty thousand and one hundred thousand asteroids revolving in orbits around the sun just beyond Mars. Some space pioneers think that these asteroids will provide the raw materials for building huge space colonies of the future.

moving through dark space

All of the planets, including some asteroids, comets and zillions of particles of space dust and our own new space satellites are themselves moving along with their parent sun through dark space. And more and more dark space. And more and more and more dark space.

in Milky Way galaxy

Our entire solar system is but one of many possible solar systems in a giant group known as the Milky Way galaxy. Just about all the stars you can

see outside on a clear night with the naked eye are other suns within this Milky Way galaxy. If you put even a small telescope to the sky you will see many thousands more Milky Way stars. Each star itself a sun to who knows how many planets.

solar system around Vega?

Very recently radio astronomers have picked up the first bits of evidence that one of the brightest stars in our summer sky, Vega, some twenty light-years away, may indeed have a solar system. And a solar system in an early stage of evolution since Vega is only about one billion years old, in comparison to our own sun's age of 4.6 billion.

where we are in our galaxy

Here is an outside view of another galaxy (we can't get a picture of the Milky Way galaxy from outside, since we are inside it). We think our Milky Way would look something like this if we could see it from outside. Our own solar system would be a tiny speck somewhere out on the edge of one of those pinwheel-like rays.

Milky Way Galaxy

only one galaxy out of billions!

Our Milky Way galaxy is only one of many billions of galaxies in the known universe. The best known and first to be discovered is the great galaxy in Andromeda, which you can just barely see with the naked eye. In a high powered telescope you can sometimes see more than one galaxy in the same view. And remember, each of these galaxies has billions of stars making it up.

"inside" and "outside"

Billions of stars in billions of galaxies. Each one billions of miles apart and billions of years ago. That is what is "inside" our universe. And "outside" too. And all around and all about.

And yet not quite all.

radio signals from space

Very recently we have begun to discover still new surprises. Radio astronomers were the first ones to suspect space was not quite as simple as we once thought. From some spots in space we could see no light with our eyes, but we could pick up strong sources of other electromagnetic waves with our electronic ears. What was causing these signals?

quasars and pulsars

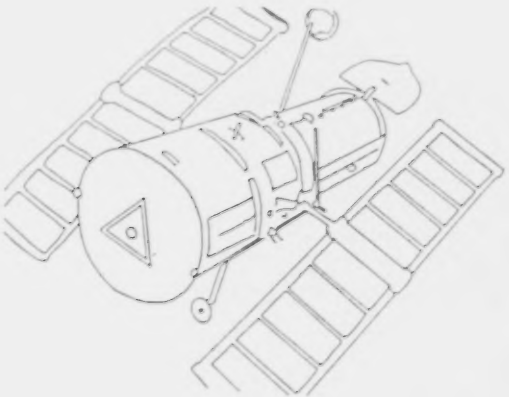
We could also see pulsating sources, and sources of radiation and energy far in excess of even the largest galaxy!

black holes

Institutes with large radio telescopes on earth are actively investigating these new quasars, pulsars and black holes.

new space telescope

NASA is launching a new space telescope that once outside the earth's atmosphere will let us see ten times clearer than any telescope on earth's surface. What new insights will come from this research is impossible to predict.



hello out there

We are also sponsoring projects to try to communicate with possible civilizations on other planets, if there are any. The theory is, if life evolves the

way we think it does, given the right chemicals and the right environment, there must be thousands, millions, even billions of other earths out there with intelligent life on them. We should someday be able to say hello. And to hear and understand their answer.

like newborn puppies

It happens routinely in our science fiction. When the day comes that it happens in our science reality, perhaps, like the newborn puppies, our eyes will begin to open and our adventure in space will have truly begun.

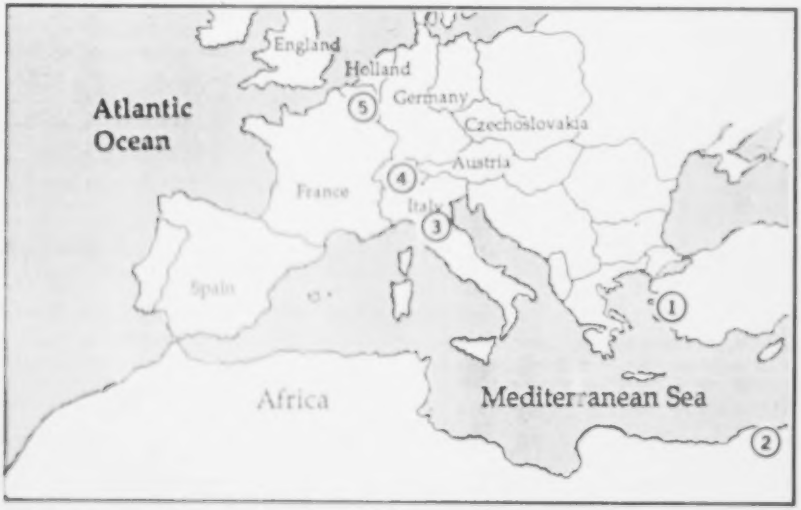
TIME ...

To understand the world of today it helps to know something about the world of yesterday. Kings and queens, wars and famines, presidents and paupers have all played a part. But more important than any of these in changing the past world into the world of today has been science and technology. The time line below will help you place important events and people in historical time.

Events in World History		Events in Science & Technology
	A.D. 1	200 B.C. Aristotle builds a model of universe in Athens, Greece
500 B.C. to A.D. 400 Roman Empire		A.D. 150 Ptolemy creates a model of universe in Egypt that is world standard for 1500 years
	500	
500-1300 Medieval Europe	1000	
1400-1600 Renaissance	1500	1543 Copernicus proposes heliocentric solar system
1776 American Revolution		1780s Herschels discover Milky Way
1939-1945 World War II		1903 Einstein and relativity
	2000	

SPACE ...

There is a saying, "If you don't know where you are going, any road will get you there." One of the important parts of knowing where you are going is a knowledge of geography. The map below will help you locate the important events and people discussed in this book.



1. Ionian Greece — Where world's first natural scientists lived and worked. Now a part of modern Turkey.

2. Alexandria, Egypt — Where the Greek astronomer Ptolemy put together famous maps and atlases that were world standards for over fifteen hundred years.

3. Northern Italy — Where Galileo lived and worked. A center of science and humanities in the Renaissance.

4. Bern, Switzerland — Capital of Switzerland where Albert Einstein worked as a patent clerk while discovering laws of relativity.

5. Belgium — At University of Louvain the Abbe Lemaitre proposed currently accepted Big Bang theory of the origin of universe.

SPIRIT ...

Time and space are meaningless without spirit. Spirit is the part in each of us that understands. The part that sees connections between words and things–connections that surprise and make sense. Study the key words, concepts and ideas below so that you can understand how time, space and spirit worked in the past–and are working today.

asteroids — Miniplanets ranging in size from a few miles to hundreds of miles in diameter. Thousands of asteroids orbit the sun just beyond Mars. (p. 20)

astronomy — The science of heavenly bodies.

big bang — A theory that the universe began in a gigantic explosion some fifteen billion years ago. (p. 11-13, 15-16)

black holes — Objects in space so massive that light itself cannot escape from them. (p. 13, 22)

Copernicus, Nicholas — A Polish astronomer who lived in the sixteenth century and was the first to propose a modern helio-centric model for the solar system. (p. 5-6)

Einstein, Albert — Physicist of the twentieth century who proposed a theory of relativity that is now widely accepted. (p. 10-11, 16)

ellipse — A near-egg-shape curve. The orbits of the planets around the sun are elliptical. (p. 6, 8, 17)

equinox — One of the two times of the year when the sun is directly over the equator, signaling the beginning of spring or fall. (p. 1)

galaxy — An assemblage of millions of stars rotating in a single system. There are billions of galaxies in the universe, including our own Milky Way. (p. 9-10, 20-21)

Galileo	An Italian physicist and mathematician who first proposed laws of motion and advanced the helio-centric view of the solar system. (p. 6-8)
gravitation, law of universal	A law proposed by Isaac Newton that explains how any two objects in the universe are mutually attracted to each other. (p. 8)
greenhouse effect	The heating of a planet like the earth from buildup of carbon dioxide in the atmosphere which reflects heat back to the planet's surface instead of letting it escape into space. (p. 17)
helio-centric	The theory that planets revolve round the sun rather than the earth. (p. 4-7)
hydrogen	The simplest element with one proton and one neutron. Most of universe is hydrogen. (p. 19)
Kepler, Johannes	Austrian astronomer who lived in the sixteenth century and first proposed that the planets moved in elliptical orbits around the sun. (p. 6)
laws of motion	Usually refers to famous three laws discovered by Isaac Newton that explain how all objects move. (p. 8)
meteor	A streak of light that occurs when an object from space falls to the earth's surface and burns up. Sometimes called a "falling star." (p. 2, 18)
Milky Way	The galaxy our solar system is a part of. Almost all of the stars you can see with the unaided eye are in the Milky Way galaxy. (p. 9, 20-21)
Newton, Isaac	English scientist who lived in the seventeenth century and discovered laws of motion and gravitation, and invented calculus. (p. 8)
planet	A large celestial body that is in orbit around the sun. There are nine planets in our solar system. In order moving out from the sun these are: **Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranius, Neptune, Pluto.** (p. 5, 17-20)

Ptolemy — A greek astronomer who put together a famous book on geography and astronomy that was the authority for over a thousand years. (p. 4)

quasar — Very distant galaxies that put out huge amounts of energy. Under study. (p. 13, 22)

relativity — A theory of Albert Einstein about space and time that is generally accepted today. (p. 10-11)

solstice — One of the two times during the year when the sun is directly over its most northern or its most southern site. The beginning of summer and the beginning of winter. (p. 1)

speed of light — 186,000 miles per second. The fastest possible speed in the universe according to the accepted theory of relativity. (p. 15)

Stonehenge — An assemblage of large stones in England, constructed about 1500 B.C. and thought to be astronomic in purpose. (p. 1)

In addition to the above, THE EXPANDING UNIVERSE also teaches about other important people, places, things and ideas. Often you can figure out the meaning of a new term by seeing how it is used in context. Make sure you know the meaning of the following (for help, check the pages listed in this Learning Power Book, as well as your dictionary and encyclopedia):

ammonia (p. 19); **Andromeda** (p. 21); **Aristotle** (p. 3-4); **axis** (p. 17); **Brahe, Tycho** (p. 6); **calculus** (p. 8); **carbon dioxide** (p. 17); **Democritus** (p. 3); **Egypt** (p. 4, 25); **Hubble, Edwin** (p. 11); **Lemaitre, Abbe** (p. 11, 25); **Mediterranean Sea** (p. 3); **Middle Ages** (p. 4, 24); **pendulum** (p. 6); **Penzias, Arno** (p. 12); **Pope** (p. 7); **Roman Empire** (p. 4); **satellite** (p. 20); **space colony** (p. 20, 29); **sulfuric acid** (p. 17); **Vega** (p. 21); **Wilson, Robert** (p. 12).

STUDY SUGGESTIONS ...

1. Of all the sciences, astronomy has no peer in exciting wonder and awe. Unfortunately, people who live in the city are usually less aware of the sky and the stars than their country cousins. Discuss the possible significance of this differenence in past ages and present day.

2. Look up the details of how Eratosthenes measured the circumference of the earth and see if you can duplicate his experiment today (in co-operation with another school at some distance).

3. Actually, most people today still seem to believe in a universe similar to Aristotle's. That is, they think it is "natural" for things to fall "down." And natural for the sun to "rise" and "set." Investigate and discuss how our everyday language and perceptions are often mistaken (and a few thousand years out of date). Does this have any practical consequences in our political, economic and social life?

4. Much has been written about the trial of Galileo and its significance to the growth of a scientific world view. Investigate for yourself this trial and its effects. See the bibliography for suggestions.

5. This book suggests that "though the Church won the battle against Galileo, it lost the war." Discuss the meaning of this statement, especially in light of conflicts between religion and science today, notably creationism versus evolution.

6. Discuss the provisional nature of scientific truth using the example of our changing views of the universe from Greeks to Ptolemy to Copernicus to Newton to Herschel to Einstein and beyond.

7. Continuing and expanding the discussion suggested in number six, discuss the ways in which scientific truth is verified or not. Relate to the way in which other theories are verified or not. There are usually a number of good current examples that offer insights into the very human nature of science. At the time of this writing superconductivity and cold fusion come to mind.

8. Led by physicists like Gerard O'Neill, many are now boldly predicting that within a decade or two we will have space colonies in the asteroid belt able to house hundreds of people in comfort and plenty. Within a century we will have colonies to house thousands, even millions of

people independent of earth. Investigate the evidence in favor and against such projects.

9. Compare and contrast the scientific studies of space colonies and communication with extraterrestial societies with those of filmmakers and fiction writers.

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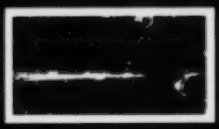

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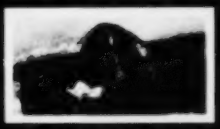

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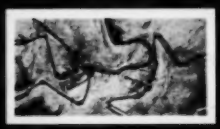

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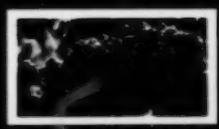

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